

## DESCRIPTION

SIGNAL DETECTING CIRCUIT FOR  
RAIN SENSOR AND SIGNAL DETECTING METHOD

## FIELD OF THE INVENTION

[0001] The present invention relates to a signal detecting circuit of a rain sensor, which is a rain-drop detecting device for automatically controlling a wiper for eliminating rain drops or the like on a 5 windshield of a vehicle, and particularly to a signal detecting circuit in which an outside-light component reducing circuit is provided. And the present invention further relates to particularly to a method for reducing an outside light component in a rain sensor.

## BACKGROUND ART

[0002] A rain sensor lights a light emitting element such as a light emitting diode (LED) at a regular frequency, irradiates the light from the light emitting element to a windshield (front glass), receives a reflected light by a light receiving element such as a photodiode (PD), takes in an output signal (pulse signal) of the PD in a microcomputer 10 and finally measures a rainfall level by detecting raindrops or an adhesion amount of raindrops.

[0003] Fig. 1 shows a signal detecting mechanism of the rain sensor. A light 11 from an LED 10 goes through lenses 12 and a prism 14 and is reflected by the surface of a front glass 16, goes through a prism 14 15 and a lens 18 and enters a PD 20.

[0004] A signal detecting circuit for detecting a pulse signal outputted by the PD 20 is, as shown in Fig. 2, comprised by an analog circuit and a microcomputer. The analog circuit 22 is comprised by a current - voltage (I-V) converter circuit 24, a band-pass filter circuit/ 25 amplifier circuit 26 and a peak hold circuit 30. The pulse signal obtained from the PD 20 is converted by the I-V converter circuit 24 from change of a current value to a change of a voltage value.

A noise component is eliminated and amplified by the band-pass filter circuit/amplifier circuit 26 and finally, a peak of the amplified pulse signal is held by the peak hold circuit 30. The held peak value is sent to a microcomputer 32.

5 [0005] The microcomputer 32 is provided with an A/D converter 34 and processes a digital value obtained from the A/D converter with software to obtain raindrop information. The rainfall level is determined from the raindrop information.

[0006] With the rain sensor with the structure shown in Fig. 1, the  
10 light received by the PD 20 includes not only the reflected light from the LED 10 but also, as shown in Fig. 3, light from the outside environment, that is, an outside light 13, and about as much as 90% of the light received by the PD is this outside light component.

The components of the outside light include those with approximately  
15 constant light intensity and those with fluctuating light intensity. Hereinafter, those with constant light intensity will be referred to as a constant outside-light component and those with fluctuating light intensity as a fluctuating outside-light component.

[0007] Fig. 4 shows an output waveform of the I-V conversion  
20 circuit 24 with the constant outside-light component. It is understood that the PD pulse signal is overlapped on the constant outside light component. A bias voltage level is a voltage level when the PD 20 is operated by a reverse bias.

[0008] Fig. 5 shows an output waveform of the I-V conversion  
25 circuit 24 with the fluctuating outside-light component. It is understood that the PD pulse signal is overlapped on the fluctuating outside-light component.

[0009] If the constant outside-light component is included in the  
outside light 13, as shown in Fig. 6, the voltage of the pulse signal  
30 outputted by the PD 20 is raised by the outside light component. When it exceeds a saturation voltage of an operational amplifier of the I-V conversion circuit 24, the signal component is crushed and a correct signal level is not inputted into the A/D converter 34.

Therefore, such a problem is caused that a correct rainfall level cannot be determined.

[0010] On the other hand, if the fluctuating outside-light component is included in the outside light, and its frequency band comes into a

5 pass band of the band-pass filter circuit/amplifier circuit 26, a high frequency component of the fluctuating outside light passes through the band-pass filter circuit/amplifier circuit 26 and as a result, the S/N ratio of an output value of the peak hold circuit 30 is deteriorated.

The microcomputer 32 cannot determine the correct rainfall level,

10 which is a problem.

[0011] There are the following two methods to reduce the above outside light component including the constant outside-light component and the fluctuating outside-light component.

[0012] The first method is a method using a visible-light cutting

15 (absorbing) prism as the prism 14 shown in Fig. 1. With this method, however, the reflected light from the LED is also attenuated by the visible-light cutting (absorbing) prism, and the signal received by the PD is lowered, which is a problem.

[0013] The second method for reducing the outside-light component

20 is a method for cutting the outside-light component by increasing the number of reflections in the prism 14 to prevent the outside light from directly entering the light receiving element. With this method, however, the size of the prism is increased and hence, the size of the rain sensor itself is increased, which is a problem.

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#### DISCLOSURE OF THE INVENTION

[0014] Therefore, an object of the present invention is to provide a signal detecting circuit provided with an outside-light component reducing circuit which can reduce an outside light component by electric treatment, not using the above-mentioned conventional

30 methods.

[0015] Another object of the present invention is to provide a signal detecting method including reduction of the outside light component.

[0016] Still another object of the present invention is to provide a method for reducing the outside light component in a signal detecting circuit for a rain sensor and an outside-light component reducing circuit.

- 5 [0017] The present invention is a signal detecting circuit which irradiates a pulse light from a light emitting element to a windshield of a vehicle, receives a reflected light by a light receiving element, processes the pulse signal from the light receiving element and inputs it to a processing unit in order to control a wiper of the vehicle,
- 10 provided with a current – voltage converter circuit for converting the pulse signal from the light emitting element to a voltage signal, an outside-light component reducing circuit provided in parallel with the current – voltage converter circuit for reducing an outside light component included in an output signal of the current – voltage converter circuit, and a band-pass filter circuit/amplifier circuit for reducing a noise of the output signal of the current – voltage converter circuit and for amplifying the output signal.
- 15 [0018] The present invention is also a signal detecting method which irradiates a pulse light from a light emitting element to a

- 20 windshield of a vehicle, receives a reflected light by a light receiving element, processes the pulse signal from the light emitting element and inputs it to a processing unit in order to control a wiper of the vehicle, comprising a step of converting the pulse signal from the above light emitting element to a voltage signal, a step of reducing an outside light component included in the above voltage signal converted as above, and a step of reducing a noise of the above voltage signal and amplifying the voltage signal.
- 25 [0019] The present invention is moreover an outside-light component reducing circuit for reducing the outside light component

- 30 in a signal detecting circuit which irradiates a pulse light from a light emitting element to a windshield of a vehicle, receives a reflected light by a light receiving element, processes the pulse signal from the light emitting element and inputs it to a processing unit in order to

control a wiper of the vehicle.

- [0020] One embodiment of such an outside-light component reducing circuit is an outside-light component reducing circuit provided in parallel with a current – voltage converter circuit for 5 converting a pulse signal from a light emitting element to a voltage signal, for frequency-separating the outside light component included in an output signal of the current – voltage converter circuit and feeding back to the input side of the current – voltage converter circuit.
- [0021] Another embodiment of the outside-light component 10 reducing circuit is an outside-light component reducing circuit provided in parallel with a current – voltage converter circuit for converting a pulse signal from a light receiving element to a voltage signal, for holding the outside light component included in an output signal of the current – voltage converter circuit and feeding it back to 15 the input side of the current – voltage converter circuit.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Fig. 1 is a diagram showing a signal detecting mechanism of a rain sensor.

Fig. 2 is a diagram showing a conventional signal detecting 20 circuit.

Fig. 3 is a diagram showing incidence of an outside light into the rain sensor.

Fig. 4 is a diagram showing a pulse signal waveform from a PD when a constant outside-light component exists.

25 Fig. 5 is a diagram showing a pulse signal waveform from a PD when a fluctuating outside-light component exists.

Fig. 6 is a diagram showing a pulse signal waveform from a PD when a constant outside-light component exists.

Fig. 7 is a block diagram showing a signal detecting circuit 30 using an outside-light component reducing circuit of the present invention.

Fig. 8 is a block diagram showing the configuration of the

outside-light component reducing circuit.

Fig. 9 is a diagram showing a concrete circuit configuration of the outside-light component reducing circuit.

Fig. 10 is a concrete circuit diagram of a signal detecting 5 circuit provided with the outside-light component reducing circuit shown in Fig. 8.

Fig. 11 is a diagram for explaining operation of the outside-light component reducing circuit.

Fig. 12 is a graph showing a relationship between the band 10 of the outside light component and a signal pass band of a low-pass filter circuit.

Fig. 13 is a block diagram showing another configuration of the outside-light component reducing circuit.

Fig. 14 is a diagram showing a concrete circuit configuration 15 of the outside-light component reducing circuit.

Fig. 15 is a concrete circuit diagram of a signal circuit provided with the outside-light component reducing circuit shown in Fig. 14.

Fig. 16 is a diagram for explaining presence of taking-in of 20 an outside light component voltage by turning a switch circuit on.

Fig. 17 is a diagram for explaining absence of taking-in of an outside light component voltage by turning a switch circuit off.

Fig. 18 is a diagram showing a timing of an LED lighting/driving pulse and a feedback switch control signal.

Fig. 19 is a diagram showing the effect of the outside-light 25 component reducing circuit in comparison between the case where there is a circuit and the case where there is not.

Fig. 20 is a diagram showing the state where the inclination of the fluctuating outside-light component becomes steep.

Fig. 21 is a diagram showing a relationship between the band 30 of the fluctuating outside light component at on/off of the switch element of the outside-light component reducing circuit and a signal pass band of the band-pass filter circuit/amplifier circuit.

Fig. 22 is a graph showing a signal detecting circuit to which a circuit for eliminating a high-frequency noise by the fluctuating outside-light component is further added.

Fig. 23 is a diagram of the pass band to which the band-pass filter circuit/amplifier circuit with a low-pass filter circuit inserted is combined.

## BEST MODE FOR CARRYING-OUT OF THE INVENTION

### [0023] First Preferred Embodiment

- Fig. 7 is a block diagram showing a first preferred embodiment of a signal detecting circuit including an analog circuit 40 using the outside-light component reducing circuit of the present invention. In the conventional signal detecting circuit in Fig. 2, the outside-light component reducing circuit 42 is inserted in parallel with the I-V converter circuit 24.
- [0024] Fig. 8 is a block diagram showing the configuration of the outside-light component reducing circuit 42. The outside-light component reducing circuit is comprised by a low-pass filter circuit 44 and an outside-light component voltage – current (V-I) converter circuit 46.
- [0025] Fig. 9 shows a concrete circuit configuration of the outside-light component reducing circuit. The outside-light component V-I converter circuit 46 is comprised by an operational amplifier 48 and a feedback resister 50. The low-pass filter circuit 44 is comprised of a capacitor 52 and a resistor 54.
- [0026] Fig. 10 is a concrete circuit diagram of a signal detecting circuit 60 provided with the outside-light component reducing circuit 42 shown in Fig. 9.
- [0027] The band-pass filter circuit/amplifier circuit 26 is provided with a switching element 62, and the peak hold circuit 30 is also provided with a switching element 64. On/off of these switching elements 62, 64 are controlled by an LED lighting/driving pulse, which will be described later.

[0028] Operation of the switching element 62 of the band-pass filter circuit/amplifier circuit 26 will be described. The pulse signal outputted from the I-V converter circuit 24 is overlapped on the bias voltage. The high-pass filter prior to the switching element 62 is  
5 connected to the ground. After passing through the high-pass filter, an inclination component (high-frequency component) is outputted and as a result, the output value might be lowered below the ground, that is, negative. If the negative output value drops below the lower limit value of an input voltage range of the operational amplifier 27 when a  
10 negative output value is inputted to the operational amplifier 27 of the band-pass filter circuit/amplifier circuit 26, it might destroy the operational amplifier. In order to prevent this, only when the LED driving pulse is at H level, that is, only during the period of the pulse signal, the switching element 62 is turned off so that the negative  
15 output value after the period of pulse signal is not applied to the operational amplifier 27.

[0029] The switching element 64 of the peak hold circuit 30 acts to discharge electricity of the capacitor 29 when turned on for preparation of the next peak hold operation.  
20 [0030] Next, operation of the outside-light component reducing circuit 42 will be described. Fig. 11 is a diagram for explaining an outline of the operation. The outside-light component reducing circuit 42 performs feedback of the outside light component (constant outside-light component and fluctuating outside-light component) all  
25 the time whether the LED is lighted or not.

[0031] Fig. 12 shows the relationship between the frequency band of the outside light component passed by the low-pass filter circuit 44 and the frequency band of the band-pass filter circuit passing the PD pulse signal. In this Fig., the PD pulse signal band is also shown.  
30 The vertical axis indicates the intensity of a signal component (V) and the horizontal axis for a frequency (f).  
[0032] 70 shows the band of the outside light component and 72 for the band of the PD pulse signal. The band 74 of the low-pass filter

circuit 44 of the outside-light component reducing circuit 42 covers the band 70 of the outside light component. Therefore, the constant outside light component and the fluctuating outside light component pass through the low-pass filter circuit 44 of the outside light

- 5 component reducing circuit 42 and are inputted to the outside-light component V-I converter circuit 46. The outside-light component V-I converter circuit 46 converts this to an electric current and feeds it back to the input side of the I-V converter circuit 24. The fed-back outside-light component current flows in the direction opposite to the 10 pulse signal current from the PD, and the outside light component is reduced. As a result, to the input of the I-V converter circuit 24, (reduced outside light component) + (signal component) are inputted.

[0033] The signal component from the I-V converter circuit 24 is sent to the band-pass filter circuit/amplifier circuit 26.

- 15 [0034] As shown in Fig. 12, the band 76 of the band-pass filter circuit/amplifier circuit 26 covers the PD pulse signal band 72, and a noise is removed. After the noise is removed, the component is amplified by the band-pass filter circuit/amplifier circuit 26, and the peak value is held at the peak hold circuit 30. The peak value is 20 inputted to the A/D converter 34 of the microcomputer 32.

- [0035] By providing the outside-light component reducing circuit in this way, the constant outside light component and the fluctuating outside light component can be reduced. Since the constant outside-light component is reduced, output of the I-V converter circuit is not 25 saturated. Also, since the fluctuating outside-light component is reduced, the S/N ratio can be improved.

#### Second preferred embodiment

- [0036] A second preferred embodiment of a signal detecting circuit including an analog circuit using an outside-light component reducing 30 circuit different from the first preferred embodiment will be described.

[0037] Except that the construction of the outside-light component reducing circuit is different, it is the same as the circuit in Fig. 7. The construction of an outside-light component reducing circuit 42

according to this preferred embodiment is shown in Fig. 13.

The outside-light component reducing circuit 42 is comprised by an outside-light component voltage holding circuit 45, and outside-light component V-I converter circuit 47 and a feedback switch circuit 43.

5 [0038] Fig. 14 shows a concrete circuit configuration of the outside-

light component reducing circuit 42. The outside-light component V-I converter circuit 47 is comprised by an operational amplifier 51, a diode 53 and a feedback resistor 50. The outside-light component voltage holding circuit 45 is comprised by a capacitor 55.

10 The feedback switch circuit 43 is comprised by an operational amplifier 57 and a feedback switching element 59. The operational amplifier 57 acts to prevent switching noise of the switching element 59 from riding on the output of the I-V converter circuit 24.

[0039] Fig. 15 is a concrete circuit diagram of the signal detecting 15 circuit provided with the outside-light component reducing circuit 42 shown in Fig. 14. Only the difference from the circuit shown in Fig. 10 is the outside-light component reducing circuit 42, while the V-I converter circuit 24, the band-pass filter circuit/amplifier circuit 26 and the peak hold circuit 30 are the same as in Fig. 10.

20 [0040] Turning on/off of the switching element 59 of the outside-light component reducing circuit 42 is controlled by a feedback switch control signal, which will be described later.

[0041] Next, operation of the outside-light component reducing circuit 42 according to this preferred embodiment will be described.

25 Figs. 16 and 17 are diagrams for explaining presence/absence of taking-in of the outside-light component voltage by turning on/off of the switch circuit 43.

[0042] Fig. 18 is a diagram showing the timing between an LED lighting/driving pulse and a feedback switch control signal.

30 (a) shows the waveform of the LED driving pulse and (b) for the waveform of the feedback switch control signal.

[0043] As shown in the waveform (a) in Fig. 18, the driving pulse for lighting the LED has the cycle of 500  $\mu$ s and the pulse width of

12.8  $\mu$ s. The LED 10 is lighted when the driving pulse is at H level and turned off at L level. Therefore, the pulse signal from the PD 20 is outputted in accordance with the driving pulse of the LED 10.

[0044] As shown in waveform (b) in Fig. 18, the feedback switch

5 control signal is at the L level for the period including before and after the period when the LED lighting/driving pulse is at the H level, while it is at the H level in the other periods. As one example, the prior period is 90  $\mu$ s and the post period is 60  $\mu$ s. These periods are somewhat varied due to interrupt processing of the microcomputer 32.

10 [0045] As shown in Fig. 16, when the LED 10 is off, the feedback

switch circuit 43 is turned on by the feedback switch control signal, and the outside-light component voltage is held in the capacitor 55 of the outside-light component voltage holding circuit 45. The held outside-light component voltage is converted to an electric current by 15 the outside-light component V-I converter circuit 47 and fed back to the input side of the I-V converter circuit 24. The fed-back outside-light component current flows in the direction opposite to that of the pulse signal current from the PD, and only the reduced outside-light component current is inputted to the input of the I-V converter

20 circuit 24.

[0046] Next, as shown in Fig. 17, when the LED 10 is on, the

feedback switch circuit 43 is turned off by the feedback switch control signal, and the signal component outputted by the I-V converter circuit 24 is not taken in. That is because the signal component should not

25 be fed back. Since the outside-light component voltage is held in the capacitor 55 of the outside-light component voltage holding circuit 45, the outside light component is fed back even during this period.

Therefore, (reduced outside light component) + (signal component) is inputted to the I-V converter circuit 24.

30 [0047] Fig. 19 shows the effect of the outside-light component reducing circuit in comparison between the case with the circuit and the case without it. The diagram on the left in Fig. 19 shows the output signal waveform of the I-V converter circuit 24 when there is

an outside light component and no outside-light component reducing circuit, while the diagram on the right shows the output signal waveform of the I-V converter circuit 24 when there are both an outside light component and the outside-light component reducing circuit.

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[0048] If the outside-light component reducing circuit is not provided, it is known that the signal component is crushed when the saturation voltage of the operational amplifier of the I-V converter circuit 24 is exceeded by the voltage rise due to the outside light

10 component.

[0049] If the outside-light component reducing circuit is provided, it is known that the outside light component is reduced and then, the saturation voltage of the operational amplifier is not exceeded and the signal component is not crushed.

15 [0050] The above is for the case where the outside light component is almost constant. The outside light component includes not only the constant outside-light component but also the fluctuating outside light component whose light intensity is fluctuated.

[0051] If the PD pulse signal whose voltage is raised by the fluctuating outside-light component shown in Fig. 5 is inputted in the I-V converter circuit 24 in Fig. 14, when the switching element 59 of the outside-light component reducing circuit 42 is turned off, as shown in Fig. 20, the inclination of the fluctuating outside-light component becomes steep. The steep inclination of the fluctuating outside-light

25 component means that the fluctuating outside-light component includes higher frequency components.

[0052] Fig. 21 shows the relationship between the band of the fluctuating outside-light component at on/off of the switching element 59 of the outside-light component reducing circuit 42 and the signal pass band of the band-pass filter circuit/amplifier circuit 26.

30 Fig. also shows the PD pulse signal band. The vertical axis indicates the intensity of a signal component (V) and the horizontal axis for a frequency (f).

[0053] The band of the fluctuating outside-light component is expanded toward the high frequency side from 71 to 73 when the switching element 59 is switched from on to off. As a result, the high-frequency component of the fluctuating outside-light component enters the pass band 76 of the band-pass filter circuit/amplifier circuit 26, and then, the high-frequency component of the fluctuating outside-light component passes through the band-pass filter circuit/amplifier circuit and is outputted. Thus, the S/N ratio is deteriorated.

In Fig. 21, 72 indicates the band of the PD pulse signal.

- 10 [0054] A signal detecting circuit to which such a circuit to eliminate high-frequency noise by the fluctuating outside-light component is added is shown in Fig. 22. This is a structure in which a fluctuating outside-light noise reducing circuit 80 is provided in the signal path of the band-pass filter circuit/amplifier circuit 26 in Fig. 15. This noise reducing circuit 80 has such a construction that low-pass filter circuits are connected in two stages. When such a low-pass filter circuit is inserted in the band-pass filter circuit/amplifier circuit 26, as shown in Fig. 23, the composite pass band is narrowed as 78 in the equivalent manner.
- 15 [0055] Therefore, the high frequency component of the fluctuating outside light is reduced, and the S/N ratio is improved.

#### INDUSTRIAL APPLICABILITY

- [0056] According to the present invention, since an outside-light component reducing circuit is provided in a signal detecting circuit of a rain sensor, saturation of output of the I-V converter circuit due to the outside light component can be prevented and noise caused by the outside light component can be reduced. Therefore, an accurate signal can be inputted in a microcomputer, whereby more accurate rainfall level can be determined.